Analysis of Impacts of Smart Grid Resources on Economics and Reliability of Electric Supply

TCIPG

Smart Grid: Economics and Reliability

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Goals

- Evaluate impacts of renewable generation, energy storage, and demand response resources on markets and operations.
- Investigate use of energy storage and demand response to facilitate integration of volatile renewable generation.
- Explore control schemes for constrained power networks with integrated renewable generation, energy storage, and demand response resources.

Fundamental Challenges

- Existing models and tools do not capture the key underlying dynamics and uncertainties inherent to power systems.
- Computational tractability, especially in planning and policy analysis, conflicts with the meaningful representations.

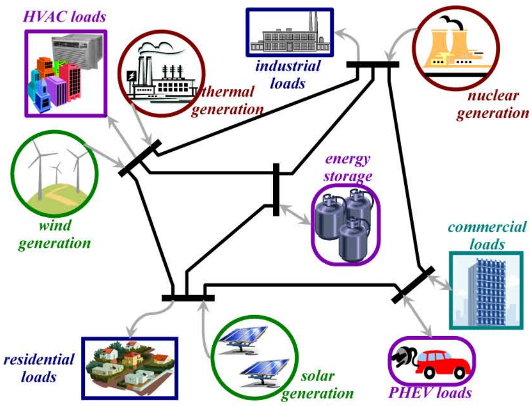

Fig. 1: Conceptual illustration of the key smart grid components considered in the analysis

Research Plan

- Questions of interest concern operational decision-making and provision of ancillary services in power grids with significant renewable generation, energy storage, and demand response resources.
- In the context of operations, we focus on volatility, dynamics, and uncertainty: stochastic models for resources have been developed with explicit consideration of physical constraints.
- Ancillary services from demand response resources are being investigated; simplified models of flexible loads have been developed for control synthesis.
- Tools: Markov decision theory, approximate dynamic programming, reinforcement learning (RL) algorithms driven by real data and model predictive control (MPC).

Broader Impact

- Proposed techniques can lead to development of operational tools that do not use artificial models for system resources and environment.
- Results can guide new policies: incentives for ancillary services from buildings, new market mechanisms, and so on.

Research Results

- Recent work [1],[2] demonstrates the application of RL techniques for control synthesis using real-world data.
- In [2], RL was integrated into the MPC framework to develop a ***computationally efficient dispatch algorithm*** for power grids with high penetration of volatile renewable resources.

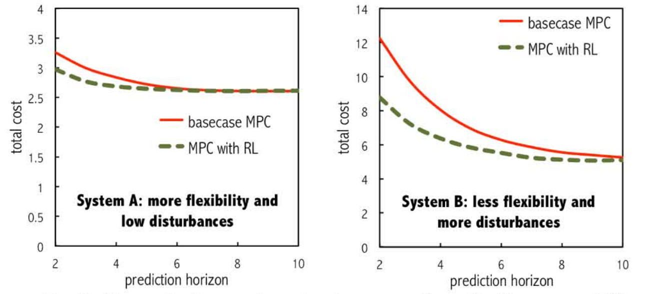

Fig. 2: Numerical experiments showcase the effectiveness of RL techniques for constrained systems subject to large disturbances

- Flexibility of HVAC loads of commercial buildings was investigated in [3] to extract ancillary services: simulations show that HVAC fan speed control alone can provide up to ***6 GW of regulation reserves*** (about 70% of the total requirements in the United States).

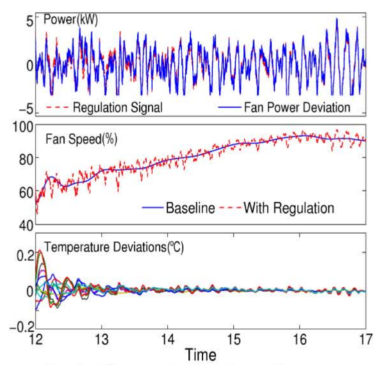

Fig. 3: Simulations of a calibrated building model demonstrate the impacts of fan speed control

Interaction with Other Projects

- Research investigates the potential benefits of demand response mechanisms; implementation hinges on availability of secure communications and metering infrastructure.
- Many activities in TCIPG focus on the development of such an infrastructure, thereby complementing our research.

Future Efforts

- Extensions to network settings are being investigated.
- Robust control schemes that can tolerate cyber-attacks to a certain extent need to be explored.

References

[1] A. Kowli and S. Meyn, "Power Node Control for Renewable Integration," in *Proceedings of IEEE PES General Meeting*, July 2012.

[2] A. Kowli et al., "Coordinating Dispatch of Distributed Energy Resources with Model Predictive Control and Q-learning," CSL technical report, UILU-ENG-12-2204, University of Illinois at Urbana-Champaign, May 2012.

[3] H. Hao et al., "Ancillary Service for the Grid Via Control of Commercial Building HVAC Systems," submitted to *American Control Conference*, June 2013.